PAIN® 154 (2013) 890–896

PAIN®

www.elsevier.com/locate/pain

Site-specific visual feedback reduces pain perception

Martin Diers [a,*,1], Walter Zieglgänsberger [b,1], Jörg Trojan [a], Annika Mira Drevensek [a], Gertrud Erhardt-Raum [a], Herta Flor [a]

[a] Department of Cognitive and Clinical Neuroscience, Central Institute of Mental Health, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany
[b] Department of Clinical Neuropharmacology, Max Planck Institute of Psychiatry, München, Germany

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

ARTICLE INFO

Article history:
Received 14 June 2012
Received in revised form 11 January 2013
Accepted 22 February 2013

Keywords:
Chronic back pain
Visual feedback
Pain intensity rating

ABSTRACT

One of the most common forms of chronic pain is back pain. Until now, nothing has been known about the influence of visualizing one's own back on pain perception at this site. We tested 18 patients with chronic back pain and 18 healthy controls, by implementing online video feedback of the back during painful pressure and subcutaneous electrical stimuli over the trapezius muscle. Pain threshold and pain tolerance were assessed. Pressure pain stimulation intensity was set to 50% above the pain threshold. Subcutaneous stimulation intensity was set to 70% above the pain threshold. Subjects had to rate pain intensity and unpleasantness after each stimulation block on an 11-point numerical rating scale. Visual feedback of the back reduced perceived pain intensity compared to feedback of the hand in both patients and controls. These findings suggest novel intervention modes for chronic back pain based on visualization of body parts by augmented reality applications.

1. Introduction

Chronic back pain (CBP) is a frequent debilitating and often treatment-resistant disorder. Compared to the proportion of the body, the back occupies only a small representation in the somatosensory and motor areas of the brain [30,32]. In contrast to other body areas, one's own back cannot be seen directly, unlike for example, the

perceived wh ization of their pain is often difficult. This diffuseness of pain and its shifting locations are central to musculoskeletal pain syndromes, and there is evidence that their body image has become disrupted [25]. This begs the question as to whether manipulating the body image can in turn influence pain perception. In patients with complex regional pain syndrome (CRPS) watching an enlarged view of the limb during movement significantly increased the pain and swelling evoked by movements, whereas shrinking the view of the limb decreased pain and swelling. These observations were interpreted as being due to a top-down effect of body image on the integration of incoming sensory information [28]. In chronic back pain patients, it could be shown that seeing the back during repeated lumbar spine movements reduces movement-evoked pain [39].

In healthy controls (HC), the focusing of attention on a tactile stimulus leads to changes in the organization or activation of the primary somatosensory cortex (SI) [23,34]. Seeing the skin of the body part being stimulated decreases 2-point discrimination

discrimination thresholds after sensory discrimination training while looking in the direction of the affected hand and seeing the mirror image of the unaffected hand [29]. A mirror at the reflection of one's own hand versus the reflection of a neutral object reduced pain perception and evoked potentials [20]. This suggests that visual feedback influences sensory discrimination and cortical organization. For non-painful tactile stimuli, visual feedback of the hand produces small effects on detection thresholds [14], whereas visual feedback can improve tactile detection on the neck, a body site normally not seen without a mirror [35]. So far we do not know how seeing one's own back during painful stimulation influences pain perception. We implemented online video feedback of the back and the hand as well as enlarged and downscaled feedback of the back. To induce relevant pain, we applied nociceptive pressure at myofascial trigger points, where repetitive stimulation can induce central sensitization and enhanced pain perception [19,40]. As a control condition, we used electrical stimuli. We

* Corresponding author. Address: Department of Cognitive and Clinical Neuroscience, Central Institute of Mental Health, Square J 5, 68159 Mannheim, Germany. Tel.: +49 621 1703 6311; fax: +49 621 1703 6305.
E-mail address: martin.diers@zi-mannheim.de (M. Diers).
[1] M.D. and W.Z. contributed equally to this work.

0304-3959 © 2013 International Association for the Study of Pain. Published by Elsevier B.V. Open access under CC BY-NC-ND license.
http://dx.doi.org/10.1016/j.pain.2013.02.022

Table 1
Demographic, psychometric and clinical data for chronic back pain patients (CBP) and healthy controls (HC).

	CBP	HC
Age [M (SD) range in years]	53.93 (9.18) 39.57-76.99	54.20 (9.16) 42.22-63.69
CESD [M (SD)]	16.41 (9.83)*	6.69 (8.18)*
Chronic pain grade[a] [M (SD)]	2.12 (1.11)	
Pain medication:		
N opioid/N nonsteroidal anti-inflammatory	0/1	0/0
Pain-related self-statements scale[b]		
Catastrophizing [M (SD)]	2.12 (0.86)	
Active coping [M (SD)]	3.32 (0.58)	
MPI	CBP patients	Pain comparison sample[c]
Pain severity [M (SD)]	3.10 (1.47)	3.55 (1.23)
Interference [M (SD)]	2.54 (1.47)	2.76 (1.27)
Life control [M (SD)]	4.46 (0.94)	3.80 (1.22)
Affective distress [M (SD)]	2.31 (1.33)	3.55 (1.23)
Support [M (SD)]	2.92 (2.29)	3.20 (1.84)
Punishing responses [M (SD)]	0.95 (1.53)	1.03 (1.20)
Solicitous responses [M (SD)]	2.90 (1.51)	2.76 (1.49)
Distracting responses [M (SD)]	3.02 (1.85)	2.19 (1.49)
General activity level [M (SD)]	2.99 (0.77)	2.62 (0.92)

CBP = chronic back pain, HC = healthy controls; M = mean, SD = standard deviation; CESD = German version of the Center for Epidemiological Studies Depression Scale (9)
* = $p < .01$.
[a] von Korff et al. (7)
[b] Flor et al. (6); MPI = West Haven-Yale multidimensional pain inventory (Kerns et al. (4), German version: Flor et al. (5)
[c] values of a German reference group of $n = 250$ patients with chronic musculoskeletal pain.

hypothesized that seeing the stimulated site compared to a control site would reduce pain intensity, and that an enlarged video feedback of the back would lead to higher and downscaled video feedback to lower pain ratings. We assumed that the pressure pain condition would be more effective than the electrical stimulation condition, as this may favor the sensitization of trigger points.

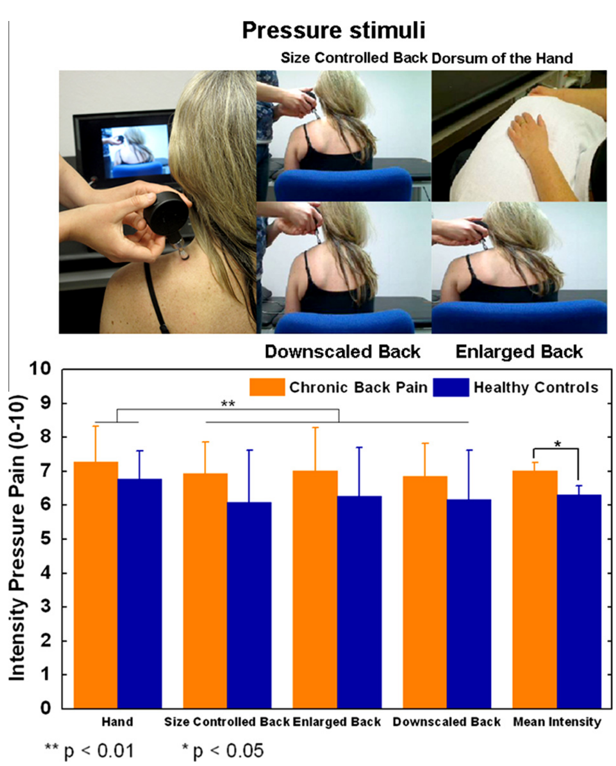

Fig. 1. (Top row) Experimental setup. Stimuli were applied to the upper back while subjects watched the image taken by a video camera placed behind them. The image showed a size control, a downscaled or an enlarged representation of their back, or the dorsum of their hand. (Bottom row) Pain intensity ratings for the pressure pain stimulation in all conditions and the mean intensity across conditions.

2. Methods

2.1. Participants

We tested 18 patients with chronic bilateral upper back pain (aged 54.74 ± 9.14 years, 5 male) and 18 HC (aged 54.69 ± 9.09 years, 6 male), matched for age and education. Table 1 lists demographic and clinical characteristics of the samples. The participants were mainly recruited through a joint case management unit established by several pain research centers in southern Germany. All patients and controls underwent medical examination. There was no significant difference between the groups with respect to age ($t_{33} = -0.016$, $P = .99$). The CBP patients had been experiencing pain for a minimum of 12 months, 9 patients for more than 10 years, and 9 for less than 10 years. None of the CBP patients took opioid medication; 1 patient took a nonsteroidal anti-inflammatory drug (NSAID); and all other subjects were medication free. We might thus have a less affected but more homogeneous sample. The patient with the NSAID was asked not to take any pain medication for 3 days before the measurement. Six of the CBP patients met the criteria for an anxiety disorder, whereas none of the CBP patients met the criteria for a current major depression or any other axis I or II mental disorder as assessed by the Structured Interview for the *Diagnostic and Statistical Manual of Mental Disorders IV* (*DSM-IV*) [2,9,10]. The HC did not fulfill any criteria for a *DSM-IV* axis I or II mental disorder. Exclusion criteria for all subjects were neurological complications, pregnancy, psychosis, use of a cardiac pacemaker, allergy to plaster, drug abuse, and current opioid intake. Informed consent was obtained, and the study was approved by the ethics committee of the Medical Faculty Mannheim, Heidelberg University and adhered to the Declaration of Helsinki.

2.2. Psychological assessment

To describe the sample in terms of clinical variables, the CBP patients completed the German Version of the West Haven–Yale Multidimensional Pain Inventory (MPI) [13,17], the Pain-Related Self-Statements Scale (PRSS) [11], and the Chronic Pain Grade (CPG) [37]. The assessment for all participants included the Center for Epidemiological Studies Depression Scale (CESD) [15,33]. The

CBP patients were significantly more depressed than the HC group [$t_{28} = -2.94$; $P < .01$] (Table 1).

2.3. Experimental design

During acute painful pressure or electrical stimulation of a myofascial trigger point (TrP1) of the trapezius muscle, online video feedback was performed. An image of the back or the dorsum of the hand was recorded and displayed on a monitor in front of the subjects. Four conditions of feedback were used: (1) feedback of the dorsum of the hand, (2) size control feedback of the back (i.e., unaltered size of the back), (3) enlarged feedback of the back, and (4) downscaled feedback of the back (Fig. 1). For the enlarged feedback, the image was contracted in the vertical dimension by a factor of 0.75; for the downscaled feedback, the image was contracted in the horizontal dimension by a factor of 0.75. Subjects reported that it seemed as if their backs were enlarged or smaller, respectively. The different types of visual feedback were implemented in separate blocks, and the blocks were then presented in random order. The different stimulation conditions were also presented in randomized order. Our primary outcome variable was the pain intensity rating. As a secondary variable effects on unpleasantness were analyzed.

2.4. Pressure stimulation

Pressure stimuli were presented with a pressure gauge device (algometer, FDN200; Wagner Instruments, Greenwich, CT) with a circular probe area of 1 cm^2 (probe diameter of 1.1 cm) capable of exerting pressure up to 20 kg/cm^2 ($\sim$200 N/cm^2). Pain threshold and pain tolerance were determined by averaging the ratings from 3 series of ascending ramps, respectively. Stimulation intensity was set to 50% above the pain threshold. We then applied a 10-s test stimulus and adjusted the stimulation intensity to yield a perceived pain intensity of 7 or 8 on a numeric analogue scale with the endpoints 0 = no pain and 10 = strongest imaginable pain. Pain unpleasantness was rated on a numeric rating scale with the endpoints 0 = not unpleasant to 10 = very unpleasant. Tonic pressure stimuli with a duration of 10 s were presented 3 times on TrP_1, and subjects rated each stimulus intensity and unpleasantness on the scales described above.

2.5. Electrical stimulation

In addition to the pressure stimulation, we implemented electrical stimulation as a non–muscle-related control condition. The electrical stimuli were always applied in 6 consecutive blocks, either before or after the muscle pain condition (counterbalanced order).

Electrical stimuli were applied using a constant current stimulator (model DS7A; Digitimer, (Hertfordshire, England, and stimuli were presented with a pair of disposable needle electrodes (20 mm long, 0.35-mm uninsulated tip, 2-mm^2 stimulation area, 0.5-cm separation (model: 9013R0272, 28G, Alpine Biomed ApS, Skovlunde, Denmark [31]. Perception threshold, pain threshold, and pain tolerance were determined by averaging ratings of 3 alternately ascending and descending series, respectively. Stimulation intensity was set to 70% above the pain threshold. We then applied 10 test stimuli and adjusted the stimulation intensity to yield a perceived pain intensity of 7 or 8. Electrical stimuli were presented in 6 trials of 30 s duration, divided by phases of no stimulation with durations of 40 to 60 s. Each 30-s trial consisted of 30 painful electrical monophasic pulses with durations of 2 ms and interstimulus intervals of 700 to 1400 ms. Electrical stimuli were always signaled with a red light fixed on the edge of the monitor, to match the available visual information to experiment 1, in which subjects had always seen the experimenter apply the pressure stimuli. Subjects had to rate pain intensity and unpleasantness after each trial, using 11-point numeric rating scales for pain intensity (0 = no pain, 10 = strongest imaginable pain) and unpleasantness (0 = not unpleasant, 10 = very unpleasant).

2.6. Apparatus

Using a video camera (Logitech, Lausanne, Switzerland) QuickCam Pro9000, 1600×1200 pixels, 30 pictures per second), the back or the dorsum of the hand was filmed and presented on a monitor (Laptop Acer; Ahrensburg, Germany) Extensa 5620, 15.4-inch monitor, 1280×800 pixels) in front of the subjects.

For the enlarged feedback, the image was contracted in the vertical dimension by a factor of 0.75; for the downscaled feedback, the image was contracted in the horizontal dimension by a factor of 0.75. This was achieved by using the software Instant Reality Player (2.0 Openbeta 7, 2009, Fraunhofer-Gesellschaft; Darmstadt, Germany; http://www.instantreality.org) [29].

2.7. Statistical analysis

Statistical analyses were conducted with IBM SPSS Statistics 20.0.0. The Kolmogorov–Smirnov test was used to test for Gaussian distribution of the data. Values exceeding the amount of 2 standard deviations from the group mean were substituted with the group mean. This was the case in 4 of 68 trials (6%) in the CBP and 3 of 68 trials (4%) in the HC in the pressure stimulation condition, and 8 of 68 trials (11%) in the CBP and 1 of 68 trials (1%) in the HC in the electric stimulation condition.

For the demographic and psychometric data, 2-sample *t*-tests were carried out. For perception and pain threshold as well as pain tolerance, 2-sample *t*-tests were calculated; hypothesis-based, 1-tailed *P* values are reported. Group differences (between-factor group) for pain intensity and unpleasantness ratings were tested using the general linear model (GLM) with stimulation (pressure or electric), body part (hand (1 level) or back (3 levels) and feedback (hand: dorsum of the hand, back: size control back, enlarged back and downscaled back) as within-group factors. Whenever the results of the Mauchly test on sphericity was significant, a Greenhouse–Geisser correction was applied. For the pain intensity of the hand and each back condition, effect sizes were computed based on the following formula: $\mathrm{ES} = \left(\mathrm{Mean}_{\text{intensity hand}} - \mathrm{Mean}_{\text{intensity size control back/enlarged back/downscaled back}}\right) / \left(\mathrm{SD}_{\text{pooled}} * \sqrt{1 - r_{\text{intensity hand intensity size control back/enlarged back/downscaled back}}}\right)$ for dependent samples. For the explorative correlational analyses in the CBP group, we devised a measure that reflects the pain reduction during the feedback of the back corrected by the effect of feedback of the hand (i.e., the pain rating in the hand feedback control condition minus the size control back feedback condition). This difference was called site-specific feedback-related pain reduction, and indicates more pain reduction during feedback from the back than the hand. In an exploratory analysis, we correlated this measure with the CESD depression scale, the MPI pain severity and interference scales, and the PRSS catastrophizing and active coping scales.

3. Results

3.1. Influence of visual feedback on pain intensity

We found a significant effect for the following: group ($F_{1,34.383} = 12.149$, $P = .001$), with higher ratings for the CBP patients; stimulation ($F_{1,231} = 79.406$, $P < .001$), with higher ratings for the pressure condition; and body part ($F_{1,231} = 10.359$, $P = .001$) (Figs. 1 and 2), with higher ratings for the hand. The different kinds of visual

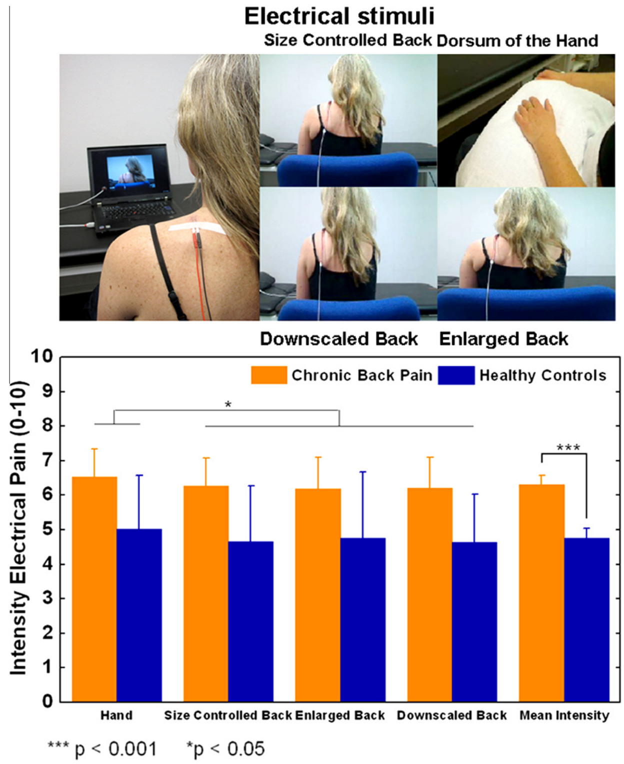

Fig. 2. (Top row) Experimental setup. Stimuli were applied to the upper back while subjects watched the image taken by a video camera placed behind them. The image showed a size control, a downscaled or an enlarged representation of their back, or the dorsum of their hand. (Bottom row) Pain intensity ratings for the electrical pain stimulation in all conditions and the mean intensity across conditions.

feedback of the back had no significant influence on acute pain intensity (factor feedback: $F_{2,231} = 0.193$, $P = .825$). Farther on there was no significant interaction of stimulation × body part ($F_{1,231} = 0.347$, $P = .556$).

3.2. Influence of visual feedback on pain unpleasentness

We found a significant effect for stimulation ($F_{1,223} = 25.592$, $P < .001$), with higher ratings for the pressure condition, and a significant effect for body part ($F_{1,223} = 5.131$, $P = .02$) (Figs. 1 and 2), with higher ratings for the hand. We found no significant effect for group ($F_{1,34.791} = 0.834$, $P = .367$). The different kinds of visual feedback of the back had no significant influence on acute pain intensity (factor feedback: $F_{2,223} = 0.14$, $P = .986$). Farther on, there was no significant interaction of stimulation × body part ($F_{1,223} = 0.223$, $P = .637$).

3.3. Correlational analyses

In the CBP, higher MPI pain severity and interference values were related to lower site-specific feedback–related reduction in pressure pain (pain severity: $r(16) = 0.516$, $P = .02$); interference: $r(16) = 0.460$, $P = .034$). The correlation between the CESD depression score or the PRSS catastrophizing and active coping scores and the site-specific feedback–related pain reduction was not significant.

3.4. Pain threshold and pain tolerance in the pressure stimulation condition

We found no significant group effect for pain threshold ($t_{32} = -0.88$; $P = .17$) or pain tolerance ($t_{32} = -0.19$; $P = .43$). The calculated stimulation intensity ($t_{32} = -0.81$; $P = .21$) and the adjusted stimulation intensity ($t_{32} = -0.92$; $P = .18$) were not significantly different between the 2 groups (means and standard deviations are given in Table 2).

3.5. Perception and pain threshold and tolerance in the electrical stimulation condition

Perception threshold ($t_{32} = 1.77$; $P = .043$) and pain tolerance ($t_{32} = 2.02$; $P = .026$) were significantly lower in CBP patients than in HCs, but there was no significant difference for pain threshold ($t_{32} = 0.306$; $P = .39$) (Table 2).

The calculated stimulation intensity did not significantly differ between the 2 groups ($t_{32} = 1.05$; $P = .15$), but the adjusted stimulation intensity was significantly lower in CBP patients ($t_{24.827} = 1.72$; $P = .048$).

4. Discussion

This study extends previous findings of the effects of visual feedback on pain to acute pressure pain. We observed that visual feedback of one's own back reduces the perceived intensity of acute painful stimuli applied to it.

This holds for both size-control and downscaled feedback of the back, but not for enlarged feedback or visual feedback from the hand. Visual feedback might exert its soothing effect on pain by at least 2 concurrent mechanisms: first, being able to monitor the stimulation of a body part increases the sense of agency, which influences body perception and can have a top-down effect on pain [20]. Second, vision provides better spatial and temporal resolution of a stimulus than somatosensation, leading to the primacy of visual over somatosensory cues in multisensory integration [8]. Thus, visual features of a stimulus are generally more confined than its somatosensory features, suggesting that visual feedback of the stimulation can attenuate perceived stimulus size and duration, in turn leading to reduced pain ratings.

There is evidence that seeing one's hand has an analgesic effect on stimuli applied to this site. While looking at their own hand, healthy controls reported reduced pain intensity ratings of laser stimuli compared to viewing a neutral object and indicated increased thermal pain thresholds [20]. In principle, these results could be solely due to a top-down effect on agency alone. However, Mancini et al. [24] found that watching an enlarged hand decreases heat pain sensitivity, whereas watching a downscaled hand increases it. Such a close relationship between perceived hand size and pain sensitivity cannot solely be explained by differences in agency; it indicates multisensory integration of somatosensory and visual information: The larger the hand, the smaller the pain related to heat. Longo et al. [21] showed that the analgesic effect of seeing the normal sized hand is associated with reduced activity in ipsilateral primary somatosensory (SI) and contralateral operculoinsular cortex. Posterior brain areas (known to be involved in the visual perception of the body) increased the effective connectivity between posterior parietal areas and the classical pain areas, including somatosensory area SII, anterior and posterior insula, and anterior cingulate cortex [21].

We observed an effect for feedback of the back but not for feedback of the hand on perceived pain intensity. This triggers questions on how visual feedback of one's back differs from visual feedback of one's hand. The hand is very well represented in the body image. This hand "template" is applied to the visual input, and hand-shaped objects are easily "incorporated." In the absence of contradicting sensory information, it is the most "natural" thing to take a hand seen in front of oneself as one's own. This capturing mechanism is responsible for the so-called rubber hand illusion (RHI) [4], which consists in touch being mislocalized to an artificial

Table 2
Perception and pain thresholds, pain tolerance and pain intensity ratings for the pressure and electrical stimuli and the four feedback conditions.

	Chronic Back Pain Patients		Healthy Controls	
	M ± SD	ES	M ± SD	ES
Thresholds				
Pressure[a]				
Pain threshold	3.77 ± 1.01		3.48 ± 0.86	
Pain tolerance	5.81 ± 1.33		5.71 ± 1.91	
Calculated intensity	5.23 ± 1.64		4.78 ± 1.57	
Adjusted intensity	5.69 ± 2.58		5.01 ± 1.64	
Intensity rating of test stimuli[c]	7.00 ± 0.78		7.06 ± 0.57	
Electric[b]				
Perception threshold	0.17 ± 0.02		0.21 ± 0.02	
Pain threshold	1.04 ± 0.11		1.08 ± 0.13	
Pain tolerance	2.37 ± 0.22		3.70 ± 0.62	
Calculated intensity	2.32 ± 0.37		2.96 ± 0.48	
Adjusted intensity	2.34 ± 0.32		3.50 ± 0.59	
Intensity rating of test stimuli[c]	7.33 ± 0.98		6.71 ± 0.61	
Ratings				
Pressure				
Intensity[c]				
Hand	7.28 ± 1.05		6.78 ± 0.83	
Size control back	6.94 ± 0.92	0.39	6.08 ± 1.54	0.89
Enlarged back	7.02 ± 1.26	0.24	6.27 ± 1.43	0.65
Downscaled back	6.85 ± 0.97	0.53	6.16 ± 1.46	0.91
Unpleasantness[d]				
Hand	6.78 ± 1.43		6.28 ± 1.71	
Size control back	6.55 ± 1.31	0.22	5.73 ± 1.95	0.48
Enlarged back	6.69 ± 1.11	0.08	5.71 ± 0.97	4.06
Downscaled back	6.45 ± 1.55	0.34	5.82 ± 1.51	0.55
Electric				
Intensity[c]				
Hand	6.54 ± 0.81		5.02 ± 1.55	
Size control back	6.27 ± 0.80	0.48	4.66 ± 1.62	0.29
Enlarged back	6.20 ± 0.89	0.54	4.75 ± 1.92	0.17
Downscaled back	6.22 ± 0.88	0.84	4.63 ± 1.40	0.32
Unpleasantness[d]				
Hand	6.61 ± 1.34		5.27 ± 2.13	
Size control back	5.74 ± 2.10	0.95	5.11 ± 1.83	0.08
Enlarged back	5.82 ± 1.87	0.83	5.00 ± 2.23	0.12
Downscaled back	5.63 ± 2.21	0.98	5.08 ± 1.84	0.09

M=mean, SD=standard deviation, ES=effect size.
[a] kg/cm^2.
[b] mA.
[c] pain intensity numeric rating scale (0 no pain – 10 strongest imaginable pain).
[d] pain unpleasantness numeric rating scale (0 not unpleasant – 10 very unpleasant); displayed are mean, standard deviations and effect sizes.

limb when one‘s own and the rubber hand are stimulated in a synchronous manner and/or the subsequent incorporation of the artificial limb into one's own body image. The RHI works because of an exaggerated preparedness to incorporate hand-shaped objects [36]. Body illusions such as the RHI have also been applied in clinical context. They provide new insights in pathological mechanisms and may yield new treatment approaches [27]. For the back, the situation is quite different: A view of one's back cannot be achieved without using tools, suggesting that our preparedness to incorporate a seen back into our body image is far less developed than our preparedness for incorporating a seen hand. In addition, incorporating a seen back to the same extent as a seen hand involves the sense of looking at one's own back from behind, that is some sort of out-of-body experience [1,3,7,18]. It is unlikely that we induced such an illusion simply by having participants watch their back on a computer screen. We suggest that a difference between the results of Mancini et al. [24] and our own results lies in the fact that, in their study, the hand was incorporated unnoticed into the body image, allowing spatiotemporal integration of visual and somatosensory input at a fairly low processing stage. In our study, participants may have incorporated the seen back to a much lesser degree, thus potentially diminishing the effects of spatiotemporal integration of the 2 modalities. It is noteworthy that, in patients with chronic hand pain, shrinking their view of the limb during movement significantly reduced the pain and the feeling of swelling evoked by movements, whereas enlarging their view induced the opposite effect [28]. In line with these findings, we observed reduced pain when the view of the back was downscaled; however, we also noted a positive effect of viewing the back in the size control condition but no effect of the enlarged feedback condition. The experience of viewing the back per se may reduce pain compared to viewing the hand, probably related to the fact that the back is usually not seen. This may have masked the negative effects of the enlarged condition. In addition, in our study the gauged intensity of experimental pain stimuli on the myofascial trigger points was assessed, whereas Moseley et al. [28] recorded the intensity of habitual chronic pain. It remains to be shown whether the differences between the studies are related to different physiological mechanisms underlying chronic and experimental acute pain. In our study, the site-specific application of tonic pressure pain to myofascial trigger points might be the most parsimonious explanation for the positive effects of visual feedback of the back. In chronic back pain patients, it could be shown that seeing the back during repeated lumbar spine movements reduces movement-evoked pain [39]. Thus, visual feedback not only improves experimentally induced pain but can also affect evoked pain during everyday movements.

In our study, pain site-specific visual feedback led to reductions in pain intensity ratings comparable to those reported for physical treatments [5], with effect sizes ranging from 0.39 to 0.91. This was true for healthy controls but also for chronic back pain patients. This is in line with findings showing that chronic back pain patients have a distorted perception of their back, related to the site of pain and associated reduced motor control [22,25]. In our patients, both habitual pain severity and interference related to pain but not depression or catastrophizing was associated with an enhanced ability to profit from site-specific feedback. Anxiety was not assessed. This suggests that the experimental pain and habitual pain interact, and that patients with more intense pain and interference may profit most from the visual feedback. The underlying mechanisms need to be investigated because this may influence how pain treatments are planned. Thus, we suggest that visual feedback of the site of pain may be beneficial to boost the effects of other interventions, such as physiotherapy or joint manipulation. We do expect that repeating such short manipulations might induce lasting effects on perceived pain intensity and perhaps also on the unpleasantness of chronic pain. The effects of the electrical stimulation might be weaker, most likely related to the fact that the skin rather than the muscle was stimulated, and to the less natural type of pain experienced with this stimulation. There was also a procedural difference related to a red light alerting to the electrical stimulation versus vision of another human applying the stimuli in the pressure condition.

This study has several limitations. Other studies quantified the effect of observing a body part during stimulation by comparing it to the effects of observing a neutral object [20]. We used viewing of another body part, the hand, as reference. This comparison may capture the specific effect of watching a body part because it is more similar in terms of visual input (brightness, color), object category, and affective involvement. It is possible that the differences between viewing the hand and viewing the back may have been influenced by attention, for example because of the novelty of viewing one's back compared to viewing the well-known hand. However, both body sites were presented in an equally unusual context, that is, a rather small video screen. As a consequence, potential effects are expected to be small.

4.1. Conclusions

This study shows that vision of a body area at which painful stimuli are presented reduces pain intensity ratings, which is in line with previous findings [20,39] suggesting that multisensory modulation could enhance pain treatments as previously suggested [12,26,38]. We also showed that this effect (a) can also be induced in body areas that cannot be seen directly, (b) is specific to the site of pain, and, (c) is also present in back pain patients. The reduced pain at hyperalgesic myofascial trigger points allows us to assume that our procedure addressed a mechanism for reducing pain in clinically relevant pain states. The alteration of the body image or visual feedback of the painful region, for example, with augmented realities, may enhance its incorporation and visuospatial integration and may decrease pain in chronic pain patients. This could be a novel gateway to the treatment of chronic back pain.

Conflict of interest statement

The authors do not have any conflicts of interest, either financial or otherwise related directly or indirectly to this article.

Acknowledgments

We thank Timm Drevensek for assistance in programming, Silvia Gubay for help with data acquisition, and Astrid Wolf for help with recruitment of the subjects. This research was supported by a European Research Council Advanced Grant "Phantom phenomena: A window to the mind and the brain" (PHANTOMMIND) project, which receives research funding from the European Community's Seventh Framework Programme (FP7/2007–2013)/ ERC Grant Agreement No. 230249 and a grant from the Deutsche Forschungsgemeinschaft FL 156/33 (to H.F.), as well as an Early Career Research Grant offered by the International Association for the Study of Pain and a Grant from the Deutsche Forschungsgemeinschaft DI 1553/3 (both to M.D). This manuscript reflects only the authors' views and the Community is not liable for any use that may be made of the information contained therein.

References

[1] Altschuler EL, Ramachandran VS. A simple method to stand outside oneself. Perception 2007;36:632–4.
[2] American Psychiatric Association. Diagnostic and statistical manual of mental disorders (DSM-IV). Washington, DC: American Psychiatric Association; 1994.
[3] Aspell JE, Lenggenhager B, Blanke O. Keeping in touch with one's self: multisensory mechanisms of self-consciousness. PLoS One 2009;4:e6488.
[4] Botvinick M, Cohen J. Rubber hands 'feel' touch that eyes see. Nature 1998;391:756.
[5] Bron C, de Gast A, Dommerholt J, Stegenga B, Wensing M, Oostendorp RA. Treatment of myofascial trigger points in patients with chronic shoulder pain: a randomized, controlled trial. BMC Med 2011;9:8.
[6] Catley M. Show me the skin! Visual input of the back improves tactile acuity. NOI Neurodynamics & the Neuromatrix 2012:12.
[7] Ehrsson HH. The experimental induction of out-of-body experiences. Science 2007;317:1048.
[8] Ernst MO, Banks MS. Humans integrate visual and haptic information in a statistically optimal fashion. Nature 2002;415:429–33.
[9] First M, Gibbon M, Spitzer R, Williams J, Benjamin L. User's guide for the structured clinical interview for DSM-IV axis. II. Personality disorders (SCID-II). Washington, DC: American Psychiatric Press; 1997.
[10] First M, Spitzer R, Gibbon M, Williams J. User's guide for the structured clinical interview for DSM-IV axis. I. Disorders (SCID-I)—clinical version. Washington DC: American Psychiatric Press; 1997.
[11] Flor H, Behle DJ, Birbaumer N. Assessment of pain-related cognitions in chronic pain patients. Behav Res Ther 1993;31:63–73.
[12] Flor H, Nikolajsen L, Staehelin Jensen T. Phantom limb pain: a case of maladaptive CNS plasticity? Nat Rev Neurosci 2006;7:873–81.
[13] Flor H, Rudy TE, Birbaumer N, Streit B, Schugens MM. Zur Anwendbarkeit des West Haven–Yale Multidimensional Pain Inventory im deutschen Sprachraum. [The applicability of the West Haven–Yale multidimensional pain inventory in German-speaking countries. Data on the reliability and validity of the MPI-D].. Der Schmerz 1990;4:82–7.
[14] Halligan PW, Marshall JC, Hunt M, Wade DT. Somatosensory assessment: can seeing produce feeling? J Neurol 1997;244:199–203.
[15] Hautzinger M, Bailer M. Allgemeine Depressions Skala (ADS) [General depression scale]. Weinheim: Beltz Test; 1993.
[16] Kennett S, Taylor-Clarke M, Haggard P. Noninformative vision improves the spatial resolution of touch in humans. Curr Biol 2001;11:1188–91.
[17] Kerns RD, Turk DC, Rudy TE. The West Haven–Yale Multidimensional Pain Inventory (WHYMPI). PAIN® 1985;23:345–56.
[18] Lenggenhager B, Tadi T, Metzinger T, Blanke O. Video ergo sum: manipulating bodily self-consciousness. Science 2007;317:1096–9.
[19] Li LT, Ge HY, Yue SW, Arendt-Nielsen L. Nociceptive and non-nociceptive hypersensitivity at latent myofascial trigger points. Clin J Pain 2009;25:132–7.
[20] Longo MR, Betti V, Aglioti SM, Haggard P. Visually induced analgesia: seeing the body reduces pain. J Neurosci 2009;29:12125–30.
[21] Longo MR, Iannetti GD, Mancini F, Driver J, Haggard P. Linking pain and the body: neural correlates of visually induced analgesia. J Neurosci 2012;32:2601–7.
[22] Luomajoki H, Moseley GL. Tactile acuity and lumbopelvic motor control in patients with back pain and healthy controls. Br J Sports Med 2011;45:437–40.
[23] Macaluso E, Frith CD, Driver J. Modulation of human visual cortex by crossmodal spatial attention. Science 2000;289:1206–8.
[24] Mancini F, Longo MR, Kammers MP, Haggard P. Visual distortion of body size modulates pain perception. Psychol Sci 2011.
[25] Moseley GL. I can't find it! Distorted body image and tactile dysfunction in patients with chronic back pain. PAIN® 2008;140:239–43.
[26] Moseley GL, Flor H. Targeting cortical representations in the treatment of chronic pain: a review. Neurorehabil Neural Repair 2012;26:646–52.

[27] Moseley GL, Gallace A, Spence C. Bodily illusions in health and disease: physiological and clinical perspectives and the concept of a cortical 'body matrix'. Neurosci Biobehav Rev 2012;36:34–46.

[28] Moseley GL, Parsons TJ, Spence C. Visual distortion of a limb modulates the pain and swelling evoked by movement. Curr Biol 2008;18:R1047–8.

[29] Moseley GL, Wiech K. The effect of tactile discrimination training is enhanced when patients watch the reflected image of their unaffected limb during training. PAIN® 2009;144:314–9.

[30] Nakamura A, Yamada T, Goto A, Kato T, Ito K, Abe Y, Kachi T, Kakigi R. Somatosensory homunculus as drawn by MEG. Neuroimage 1998;7:377–86.

[31] Niddam DM, Graven-Nielsen T, Arendt-Nielsen L, Chen AC. Non-painful and painful surface and intramuscular electrical stimulation at the thenar and hypothenar sites: differential cerebral dynamics of early to late latency SEPs. Brain Topogr 2001;13:283–92.

[32] Penfield W, Boldrey E. Somatic moter and sensory representation in the cerebral cortex of man as studied by electrical stimulation. Brain 1937;6:389–443.

[33] Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. Appl Psychol Meas 1977;1:385–401.

[34] Schaefer M, Heinze HJ, Rotte M. Observing the touched body magnified alters somatosensory homunculus. Neuroreport 2008;19:901–5.

[35] Tipper SP, Phillips N, Dancer C, Lloyd D, Howard LA, McGlone F. Vision influences tactile perception at body sites that cannot be viewed directly. Exp Brain Res 2001;139:160–7.

[36] Tsakiris M, Haggard P. The rubber hand illusion revisited: visuotactile integration and self-attribution. J Exp Psychol Hum Percept Perform 2005;31:80–91.

[37] Von Korff M, Ormel J, Keefe FJ, Dworkin SF. Grading the severity of chronic pain. PAIN® 1992;50:133–49.

[38] Wand BM, Parkitny L, O'Connell NE, Luomajoki H, McAuley JH, Thacker M, Moseley GL. Cortical changes in chronic low back pain: current state of the art and implications for clinical practice. Man Ther 2011;16:15–20.

[39] Wand BM, Tulloch VM, George PJ, Smith AJ, Goucke R, O'Connell NE, Moseley GL. Seeing it helps: movement-related back pain is reduced by visualization of the back during movement. Clin J Pain 2012;28:602–8.

[40] Xu YM, Ge HY, Arendt-Nielsen L. Sustained nociceptive mechanical stimulation of latent myofascial trigger point induces central sensitization in healthy subjects. J Pain 2010;11:1348–55.